**Question 1.** Consider the signal below on the left.

![Graph showing time-domain and frequency-domain representation of a signal](image)

1) Write out the time-domain equation for the signal: \( V(t) = 10 \sin(2\pi (2000000)t) \) V

\[ T = 0.5\mu s, \text{ i.e. } f = \frac{1}{T} = \frac{1}{0.5\mu s} = 2 \text{ MHz} \]

2) On the axes to the right, plot the frequency domain representation of the signal. (Make sure to label axes and relevant values.)

**Question 2.** Circle all of the following which are advantages of using modulation. (Could be more than one answer.)

- (i) Systems can have smaller antennas due to higher carrier frequencies
- (ii) Modulated signals have smaller bandwidth than baseband signals
- (iii) Signals can be deconflicted by modulating at different carrier frequencies (i.e. Frequency Division Multiplexing)
- (iv) Modulation enables a more extensive use of the EM spectrum since higher frequencies are available
- (v) Modulation makes it possible to transmit digital signals via free space, which would otherwise be impossible since antennas can’t send DC signals

**Question 3.** What is the length of the driven element in a 300 MHz Yagi antenna?

Find wavelength: \( \lambda = \frac{c}{f} = \frac{3\times10^8 \text{ m/s}}{300\times10^6 \text{ Hz}} = 1\text{ m} \)

Driven element of a Yagi is a dipole, which has length \( \frac{\lambda}{2} = \frac{1\text{ m}}{2} = 0.5\text{ m} \)

**Question 4.** Given the frequency domain representation of an AM signal shown below, write out the equation for the carrier signal \( v_c(t) \) and the equation for the baseband signal \( v_m(t) \), including units.

\[ v_c(t) = 10 \sin(2\pi (150000)t) \text{ V} \]

\[ v_m(t) = 4 \sin(2\pi (5000)t) + 6 \sin(2\pi (2500)t) \text{ V} \]
**Question 5.** You are designing an amplifier for a sensor system, which must take 5 mW as input power and amplify it to produce an output of 14 dBm (+/- .5dBm). You check with the lab techs, and they have the three amplifiers $A_1, A_2, A_3$ (shown here to the right) available. Select which amplifiers you would use (in which arrangement) and draw them into the box below. **Show all work for full credit.**

\[
P_{\text{in}} = 5 \text{mw} \\
= 10 \log(5) \text{ dBm} \\
\approx 7 \text{ dBm}
\]

Required amplification in dB is \( P_{\text{out}}[\text{dBm}] - P_{\text{in}}[\text{dBm}] = 7 \text{ dB} = A_1 + A_2 \)

Can also do this by converting \( P_{\text{out}} \) to mW, finding required amplification as a unitless gain, and then converting \( A_1 \) and \( A_2 \) to unitless gain and considering their product.

**Question 6.** Consider the antenna radiation pattern shown to the right.

1) What is the half-power beamwidth for the main lobe?
   
   Half-power (i.e. -3dB) occurs at 330 deg. and 30 deg., so the half-power beamwidth is 60 deg.

2) What is the Side-Lobe-Level (SLL) for the rear lobe?
   
   \[
   \text{SLL(dB)} = G_{\text{main}}(dB) - G_{\text{side}}(dB) = 0\text{dB} - (-12\text{dB}) = 12\text{dB}
   \]
**Question 7** The radio tower for WNAV AM 1430 in Annapolis is approx. 386 feet tall.

1) What is the nominal radio horizon line-of-sight distance for this radio tower (in miles)?

\[ d[\text{miles}] = \sqrt{2h[\text{feet}]} = \sqrt{2(386)} = 27.8 \text{ miles} \]

2) A friend in Gaithersburg (approx. 40 miles from Annapolis) claims that she regularly hears WNAV broadcasts at all hours of the day. Which radio propagation phenomenon would be the MOST likely reason for this?

   Ground wave propagation. (This is farther than line-of-sight, but two close for sky waves.)

3) Another friend who lives in New York City (approx. 200 miles from Annapolis) claims that one night he heard a radio broadcast from WNAV, but your friend in Philadelphia (approx. 100 miles from Annapolis) didn’t hear it. Which radio propagation phenomenon would be the MOST likely reason for this?

   Sky wave propagation. (This is farther than ground waves would travel, and it would explain why the transmission skipped Philadelphia but arrived in NYC.)

**Question 8.** You and your lab partner stand 100m apart from each other, each holding a standard dipole antenna. Your lab partner transmits a signal with a transmit power of 10W, and you receive .153mW. Assuming an ideal propagation environment, at what frequency is your lab partner transmitting?

For a dipole, gain \( g = 1.64 \).

Rearranging the Friis free space equation, we have

\[ \lambda^2 = \frac{P_{\text{rec}}(4\pi d)^2}{P_{\text{trans}} g^2} = \frac{0.00153W (4\pi(100))^2}{10W (1.64)^2} \]

Solving, we have \( \lambda \approx 3m \), i.e. \( f = \frac{c}{\lambda} = 100 \text{MHz} \)

**Question 9.** A communication system uses the QPSK digital modulation scheme illustrated by the constellation diagram to the right. A signal is received (below left) with the indicated phase changes. Write out the bitstream that has been received.

\[
\begin{array}{cccccccc}
00 & 01 & 11 & 10 & 00 & 11 & 01 & 10 \\
\end{array}
\]
Question 10. The figure below is a graph of the signal

\[ V(t) = \sin(2\pi(22)t) + 2\sin(2\pi(15)t) + 5\sin(2\pi(2)t) \]

Suppose the signal is sampled at a 20Hz sampling rate and quantized with a 3-bit quantizer with a range of -8V to +8V.

1) Circle the 5th sample point.
   Sampling period is 1/20 = .05 seconds. First sample is at time 0, so fifth sample is at time 0.2.

2) Next to the 5th sample point, write the binary number that will be assigned to that sample.
   Since we’re using a 3-bit quantizer and the range is -8V to +8V, we have 2^3=8 possible levels, as shown above. The fifth sample point falls in the sixth quantization level, i.e. it is assigned a value of 101.

3) Will the conversion from digital back to analog suffer from aliasing? Briefly explain why or why not.
   To avoid aliasing, we have to sample at higher than the Nyquist frequency.
   The Nyquist frequency = Two times the highest frequency component = 2*22Hz = 44Hz.
   Since our sampling rate is 20 Hz which is less than the Nyquist frequency, we will have aliasing.